The Silicon TPC System

EUDET Annual Meeting

20 October 2009

Jan Timmermans

NIKHEF

JRA2 activity/task

- Silicon TPC readout (“SITPC”)

    - development TimePix chip
    - development diagnostic endplate module incl. DAQ

Purpose: a SiTPC based monitoring system

Partners:

ALU Freiburg, Bonn, CEA Saclay, CERN, NIKHEF

SITPC Tasks:

- ✓ Develop the Timepix chip that allows to measure the 3rd coordinate (drift time)
- ✓ Implementation of Timepix together with GEM and Ingrid into diagnostic endplate system (with GEM working; with Ingrid in progress)
- ✓ Performance measurements in test infrastructure at DESY (analysis GEM+Timepix data in progress)
- ✓ Develop simulation framework (continues)
- ✓ Develop DAQ system and integrate in overall DAQ of EUDET infrastructure (first used in June’09)

“final” SITPC deliverable is endplate infrastructure consisting of (at least) one LP module with Timepix readout

- Original “due” date was month 36
- First delayed to month 38, later to month 42 (done June’09)

Reasons:

- Difficulties with control and readout of 4 or 8 chips on multichip PCBs
- Difficulties with reliable production of integrated grids (INGRIDs) in ‘wafer’ postprocessing technology

Today: most of the difficulties overcome, although large quantities are still not trivial

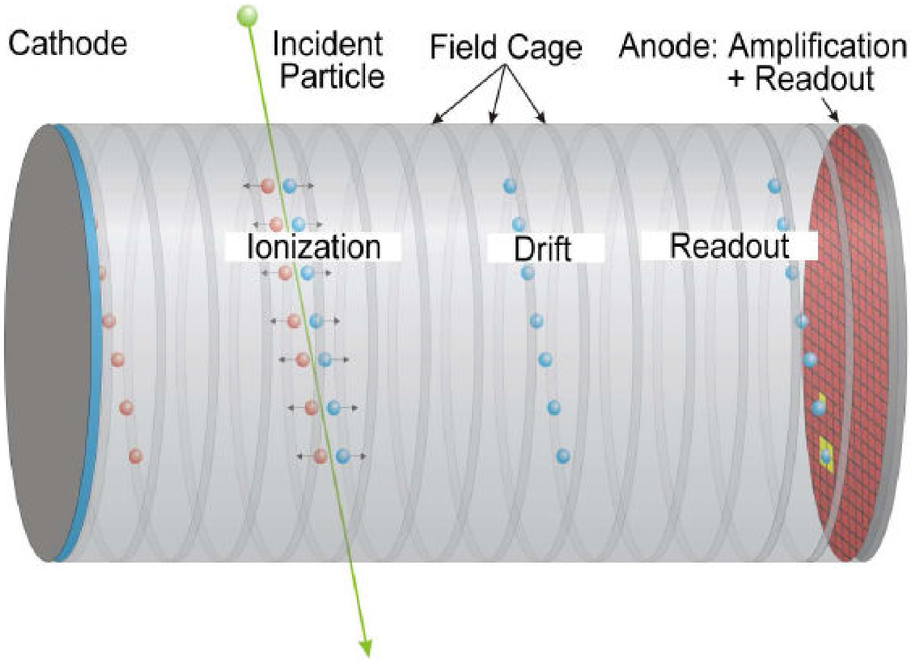
Milestone/deliverable has 3 'legs':

- one LP endplate module with triple-GEM (Bonn/Freiburg) read out by system of 2x4 Timepix chips; operational June'09 in T24

- one LP endplate module with Ingrid, a Micromegas-like integrated grid (Saclay/Nikhef), with 8 Timepix chips; 8 (+3 spare) Ingrids produced and now at Saclay, to be mounted on 8-chip TPC endplate module

- One (or more) small detector(s) with 'Quad' Ingrids = "traveling infrastructure"; detector with 4 Ingrids ready; to be tested soon

TPC with MPGD

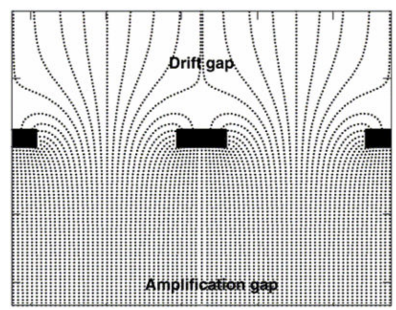


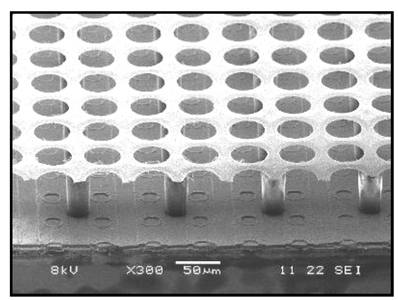
MicroPatternGasDetector
MPGD
not limited by **E** x **B** effects

- **Two gas amplifications:**

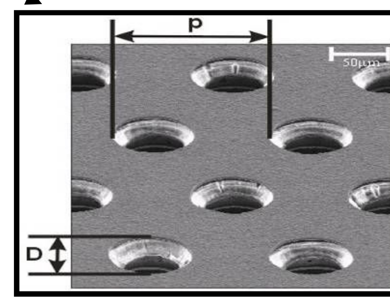
- **Analog TPC**
  with standard pad readout
  (need signal broadening)
  Digital TPC
  with CMOS pixel readout

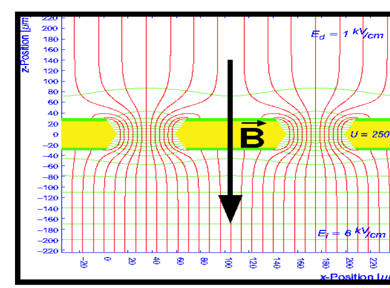
MicroMegas





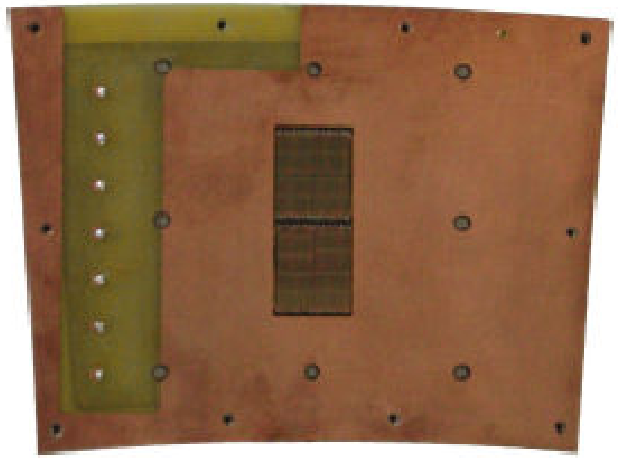
GEM

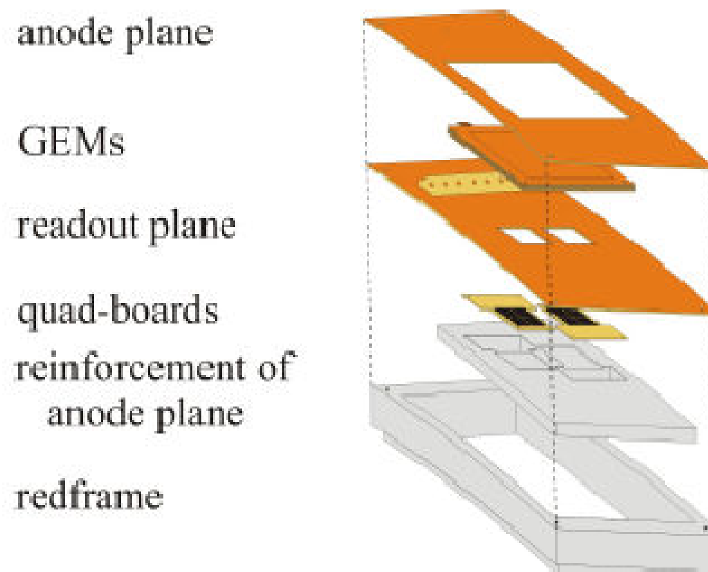




Module with GEMs & Timepix

Bonn/Freiburg





<u>Gas amplification stage:</u>

3 standard CERN GEMS (60/70/140)

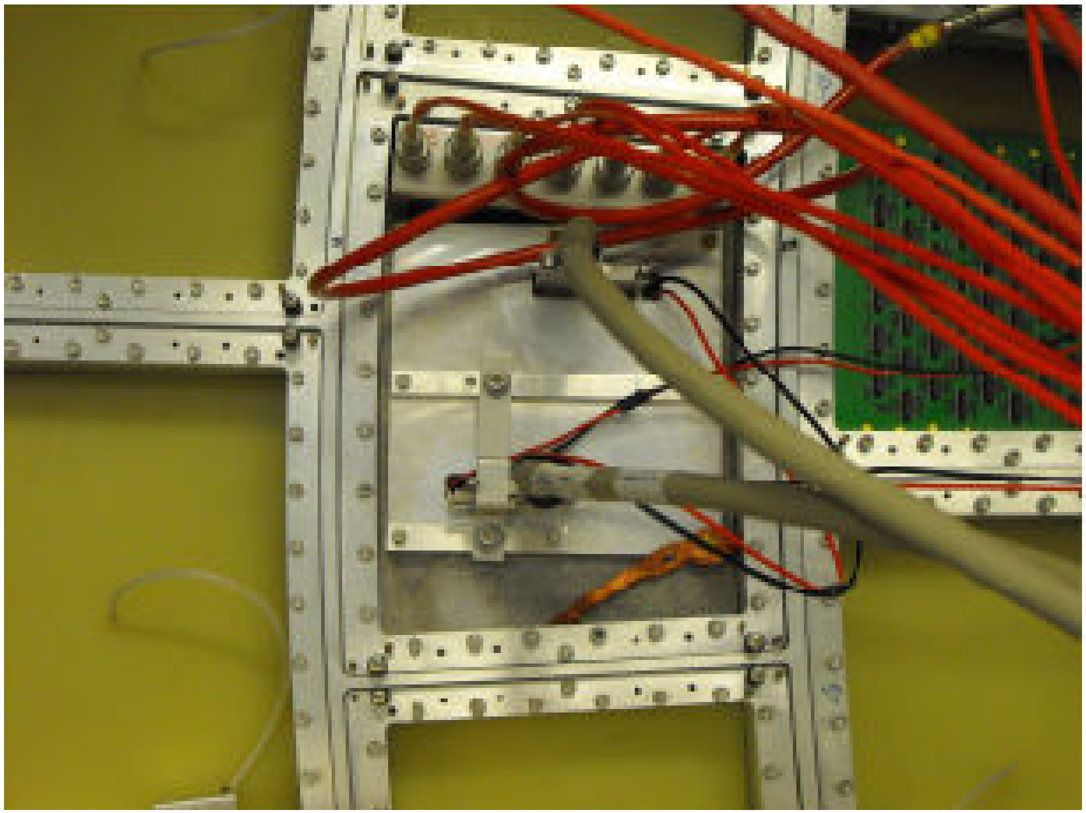
1 mm spacing between GEMs

<u>Readout:</u>

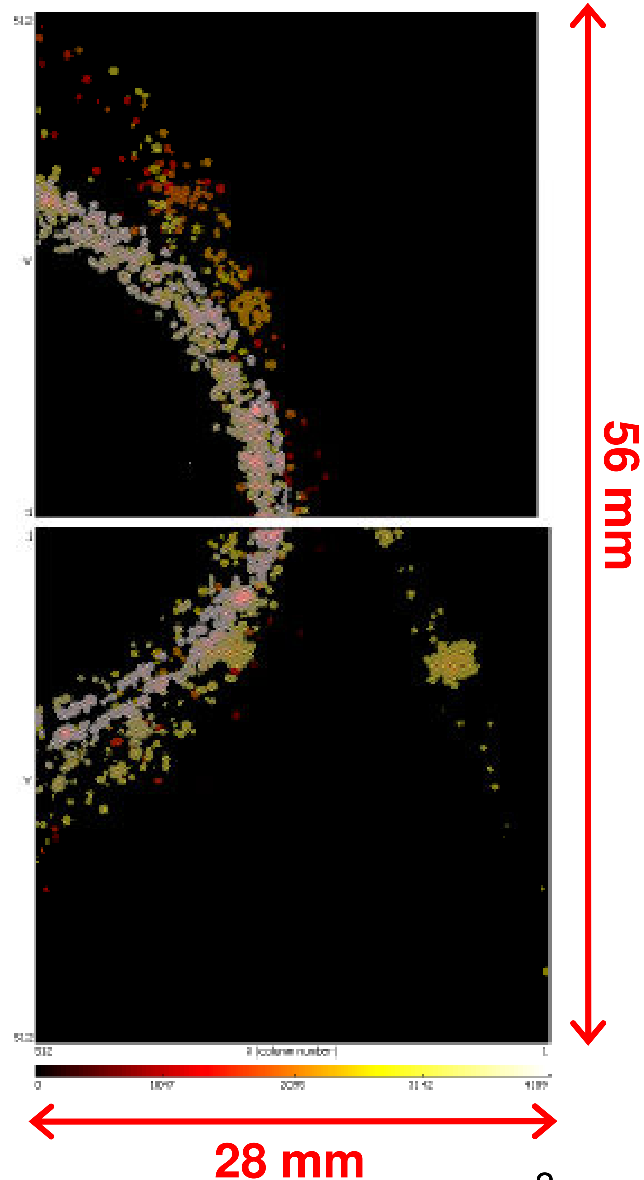
2 quadboards (4 Timepix chips each)

Nikhef

Triple-GEM module with readout by 8 Timepix chips: 16 cm2 active area, 0.5M channels

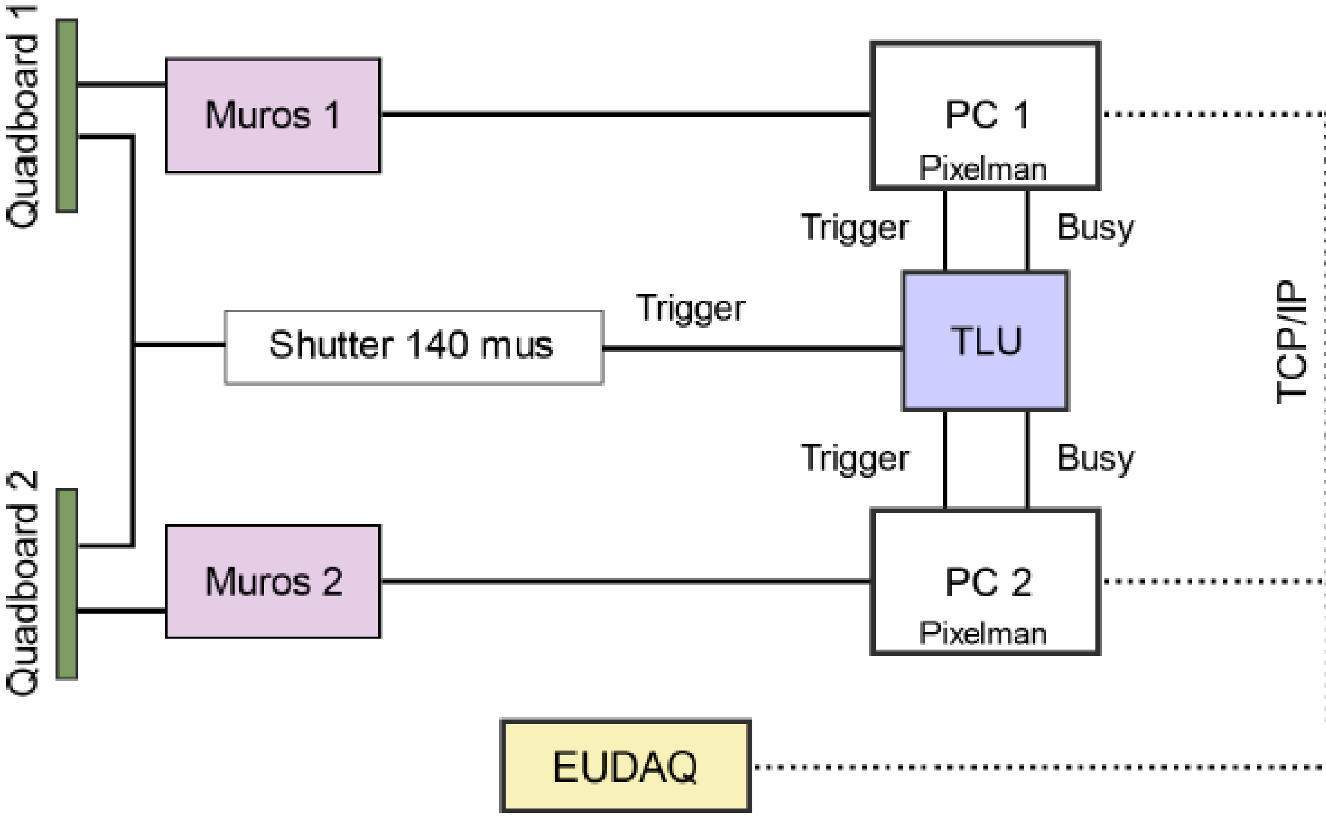


Bonn/Freiburg



Readout scheme

Using 2 Muros systems synchronized by TLU and EUDaq



Data is written directly in the LCIO format.

4

Still need some hardware 'on loan' from institutes (e.g. Muros interfaces)

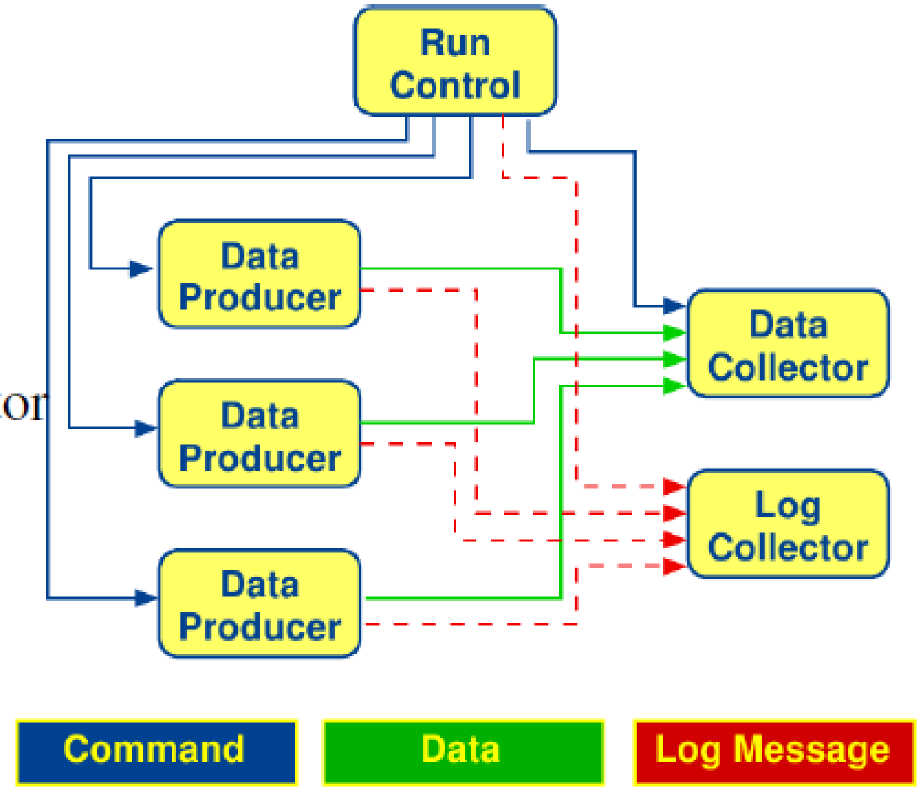
EUDAQ: The Eudet Data Acquisition System

<u>DataProducer:</u> Pixelman plugin communicates with EUDAQ

- Receives commands from Run Control
- Sends data to Data Collector
- Sends messages to Log Collector

<u>DataCollector:</u>

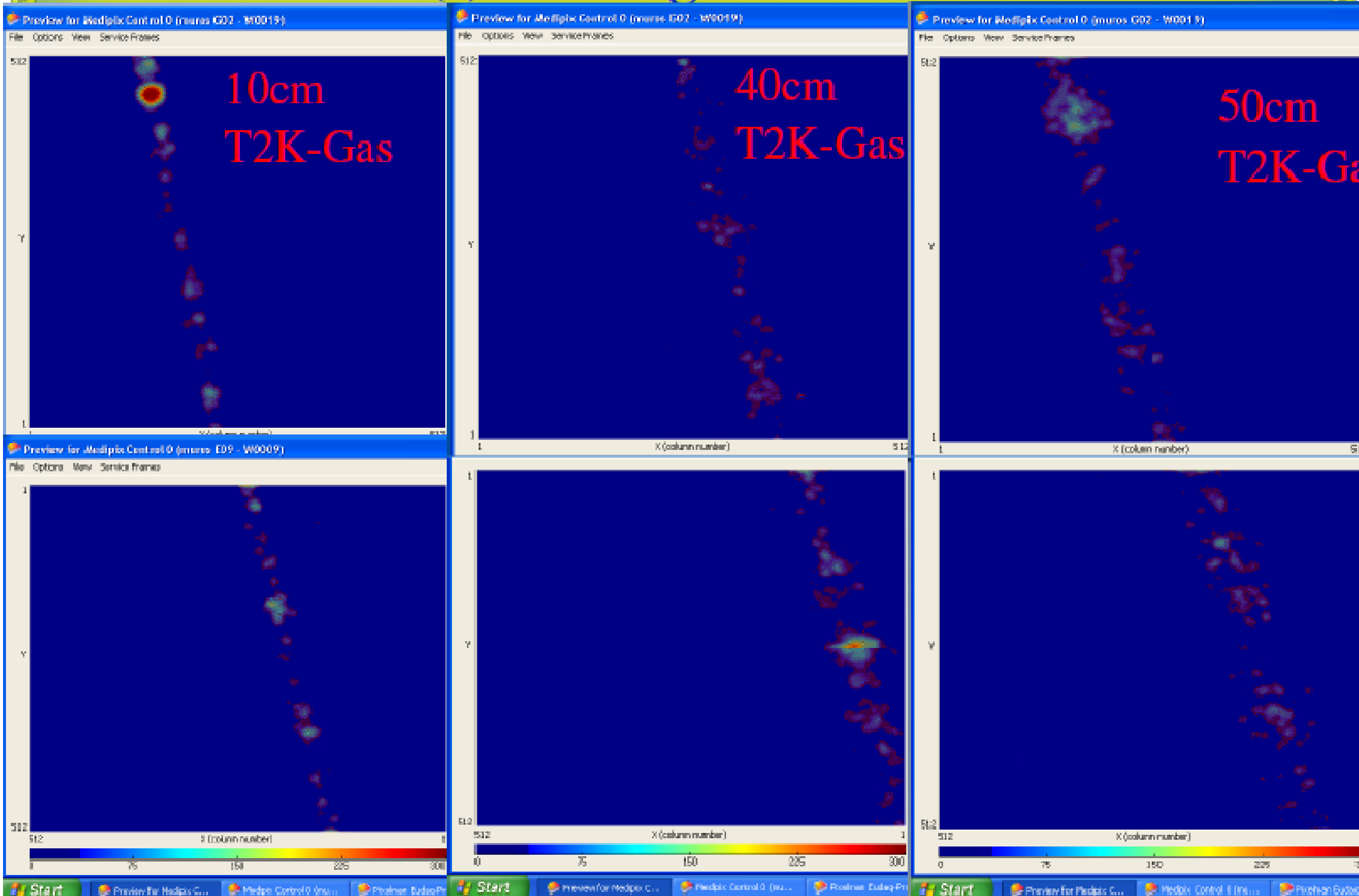
- Receives raw data
- Performs event building
- New: Plugin mechanism
- LCIO converter plugin for every raw data format



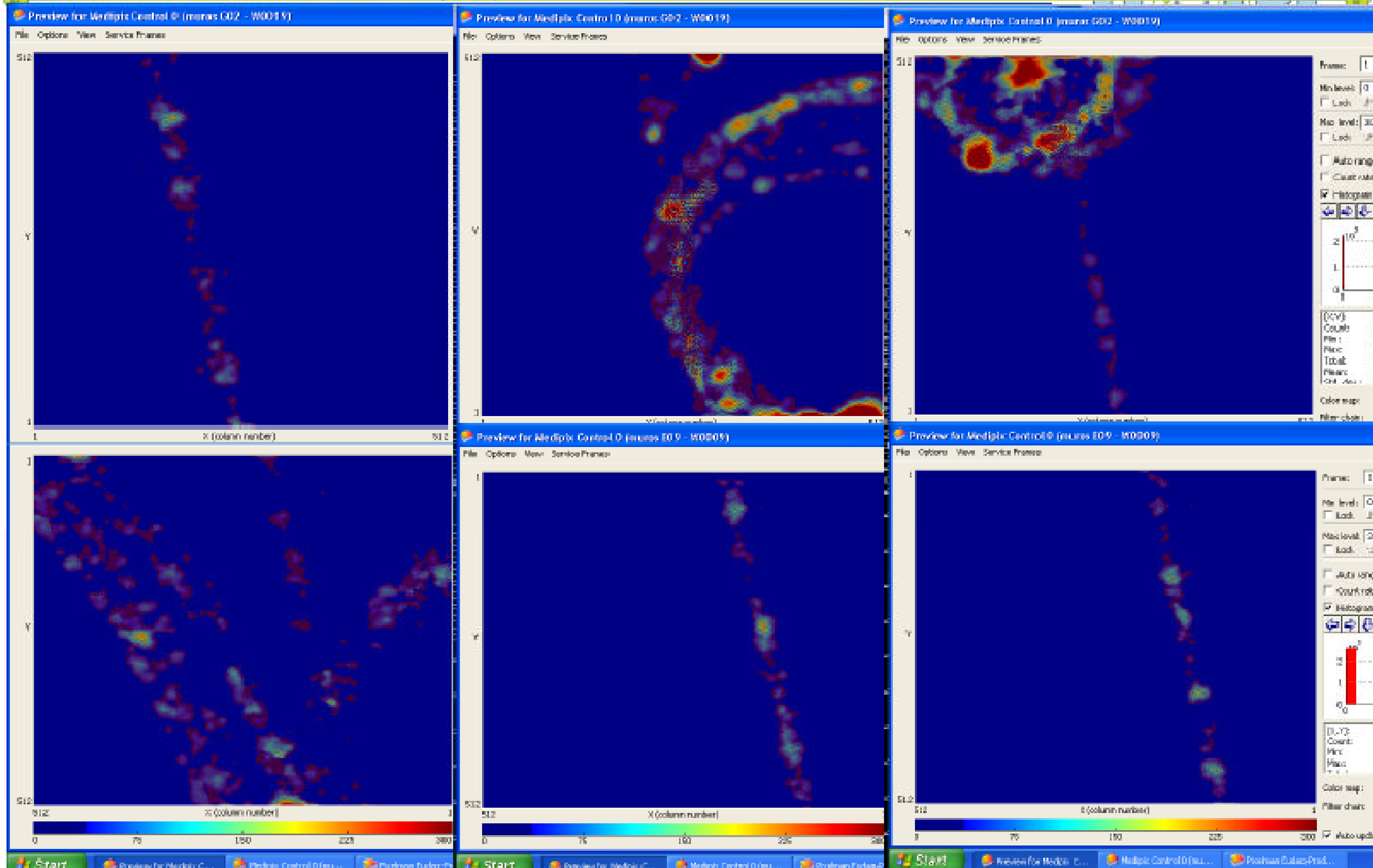
universitätbonn

5

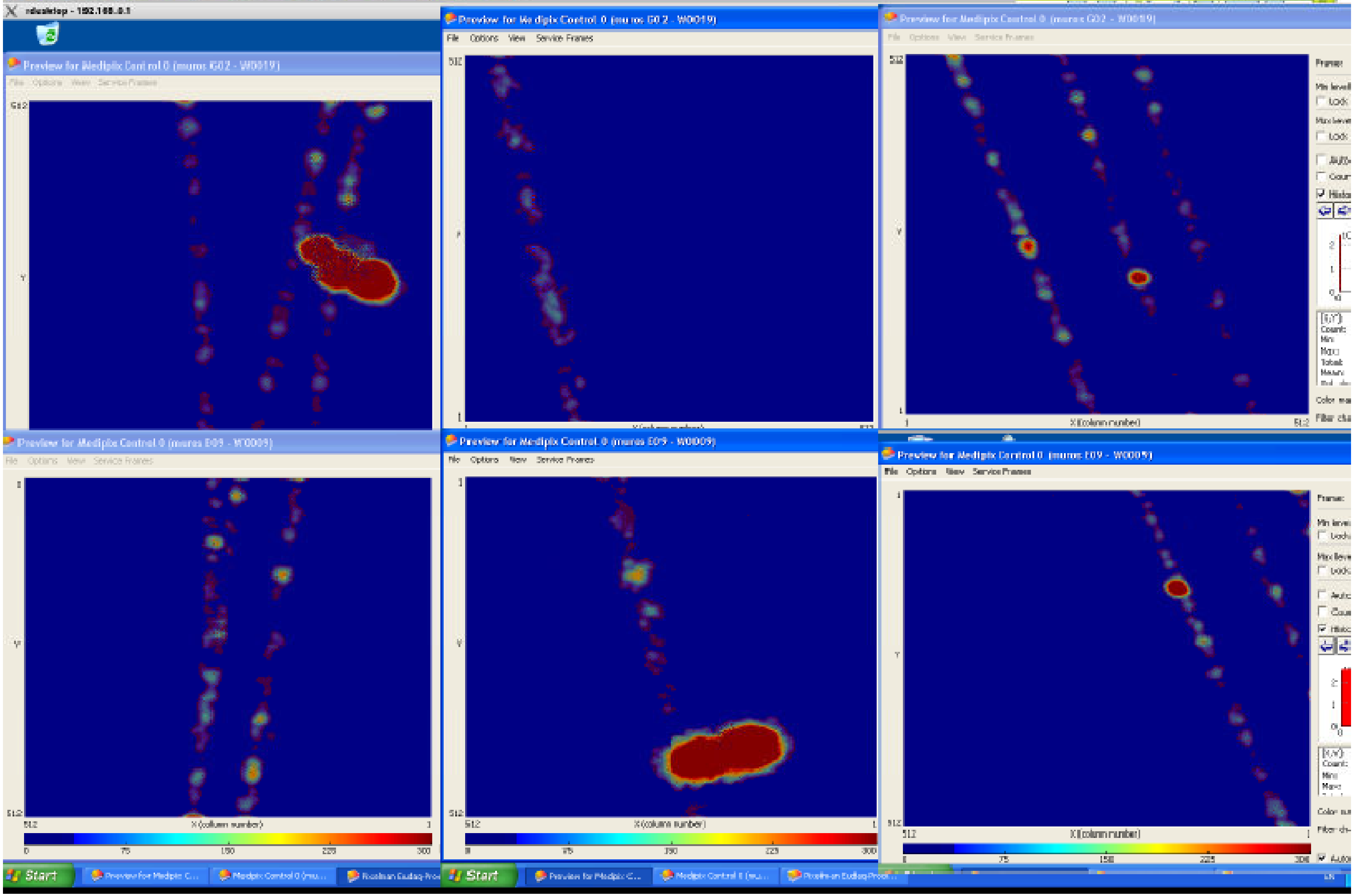
Some Pictures (I) – straight tracks



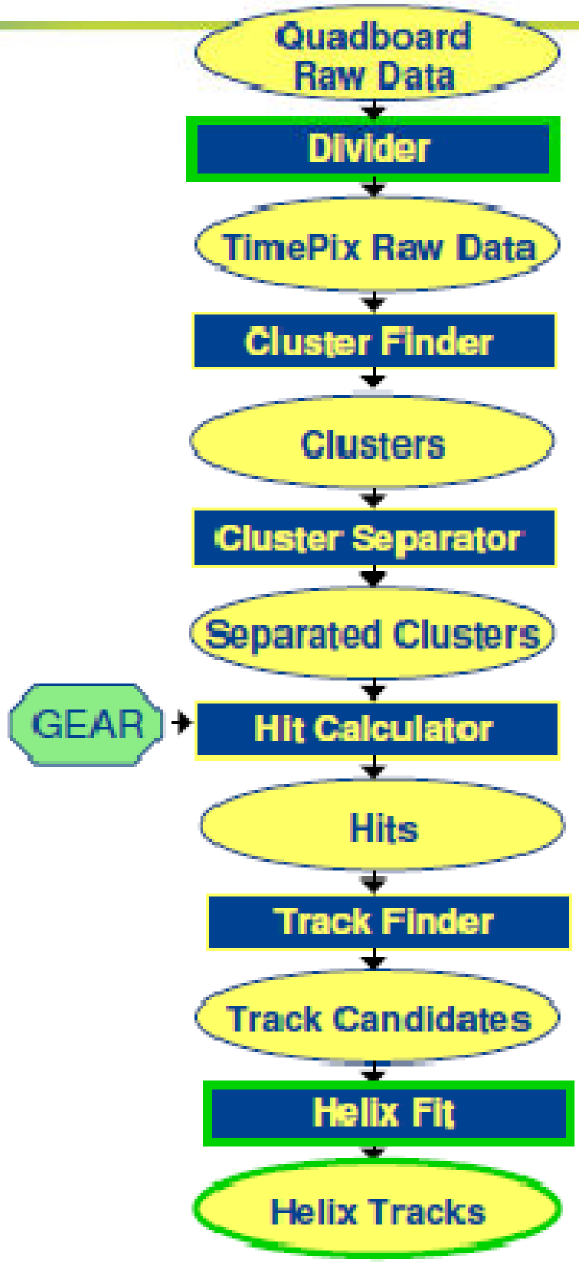
Some Pictures (II)



Some Pictures (III)



Reconstruction with MarlinTPC



Reconstruction flow:

- Find individual clusters
- Separate clusters
- Calculate 3D hits
- Find tracks
- Fit tracks

→ already done for single chips without magnetic field

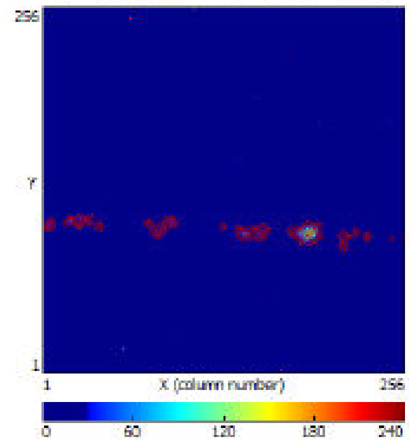
Needed for LP module:

- Alignment of the individual chips
  - Subdivide Quadboard raw data into data of single chips
  - Include the exact geometric alignment of the chips with GEAR
- Adapt existing processors for multiple chips
- Fitting of curved tracks

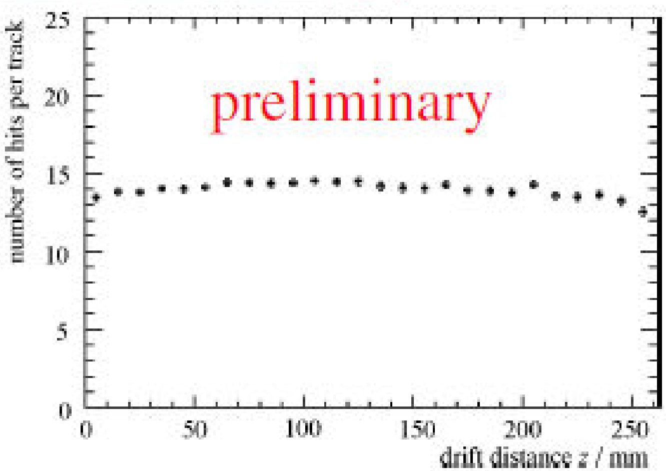
High Magnetic Fields

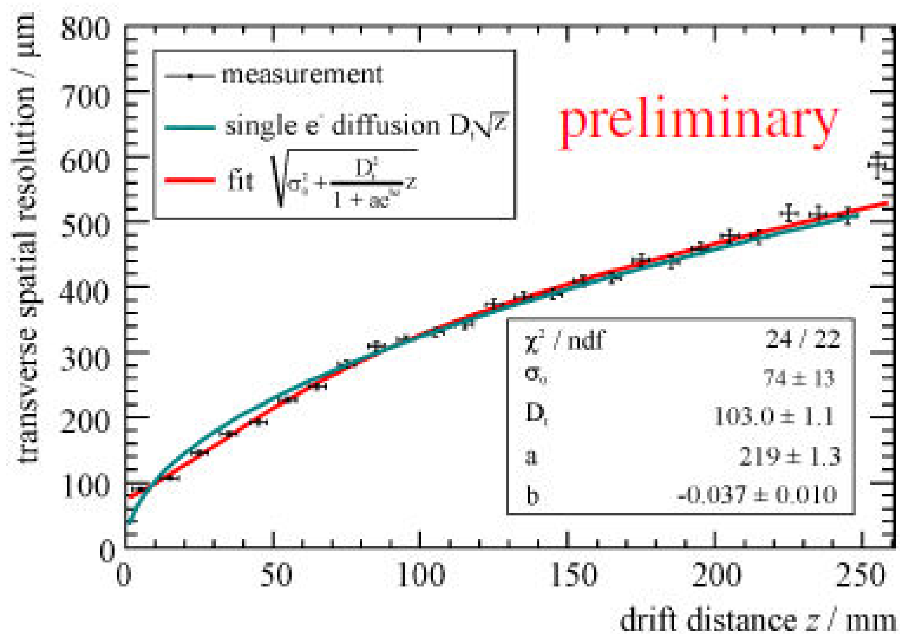
old ZEUS compensation magnet
supraconducting solenoid
reaches up to 5 T

detector is operated in magnet
first results with low statistics



He:CO_2 70:30
at 4T





Motivation for Larger pixels

Freiburg

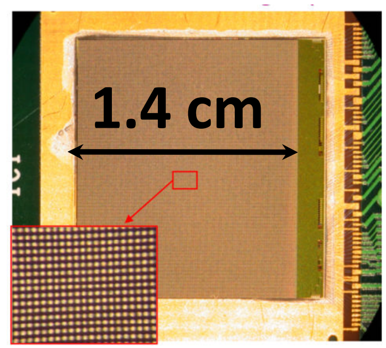
- **Charge of cluster is spread over several pixels:**
  - **Reduces number of e^- per channel.**
  - **Increases effective threshold.**
  - **Requires high gas gain to detect minimum ionizing particles.**
- **Large pixels:**
  - **Collect more charge per pixel ⇒Reduce effective threshold.**
  - **Need less gas gain ⇒ Smaller number of positive ions.**
  - **Optimize pixel size versus spatial resolution.**
  - **Strong diffusion between cascaded GEM stack.**

⇒Very small pixels not necessary

Pixel Enlargement IZM

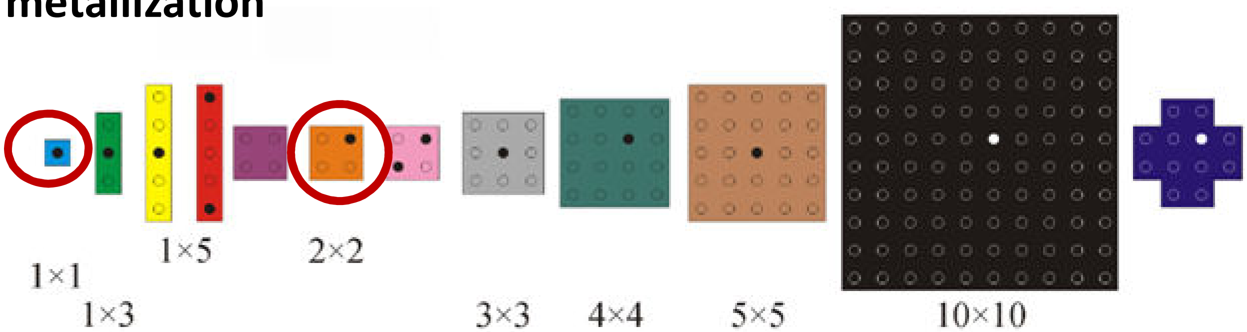
TimePix is used as highly segmented charge collecting anode

- Post processing of complete *wafer from Bonn* group by IZM Berlin:
  - »Different pixel sizes
  - »Different pixel geometries
- Two post processed TimePix tested
  - •1x1: pixel metallization extended from ≈20x20 µm² to 50x50 µm²
  - •2x2: pixel size extended to 105x105 µm² by passivating 3 out of 4 pixels and adding metallization

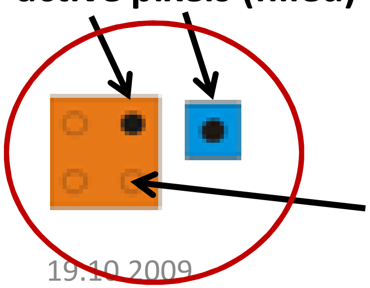


Dimensions & Features

- 256 x 256 pixels²
- 55 x 55 µm² pixel size
- 14 x 14 mm² active area
- Measures Time Over Threshold (TOT)
- External test pulse can be injected in pixels



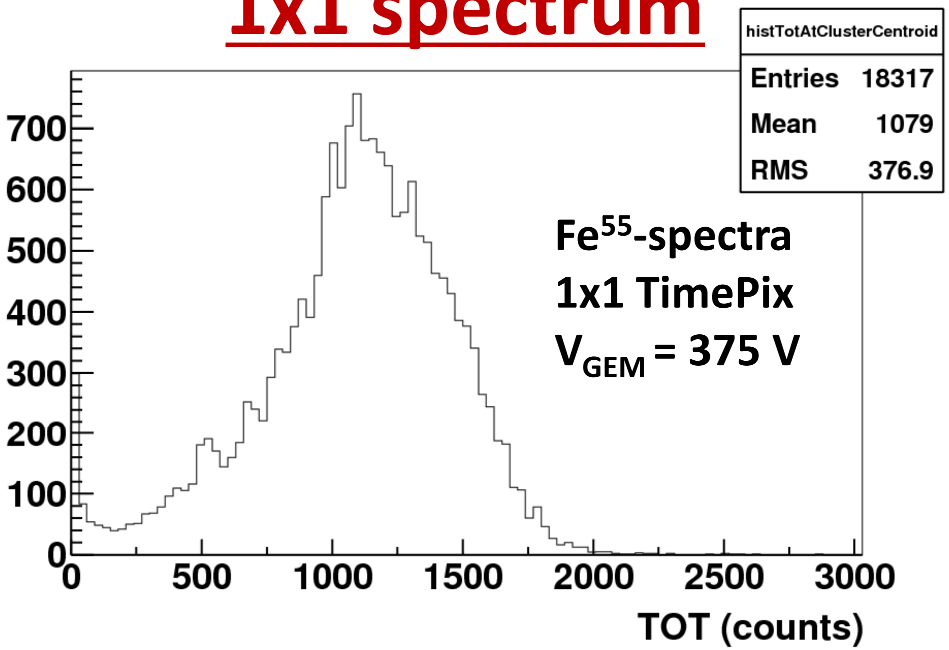
active pixels (filled)



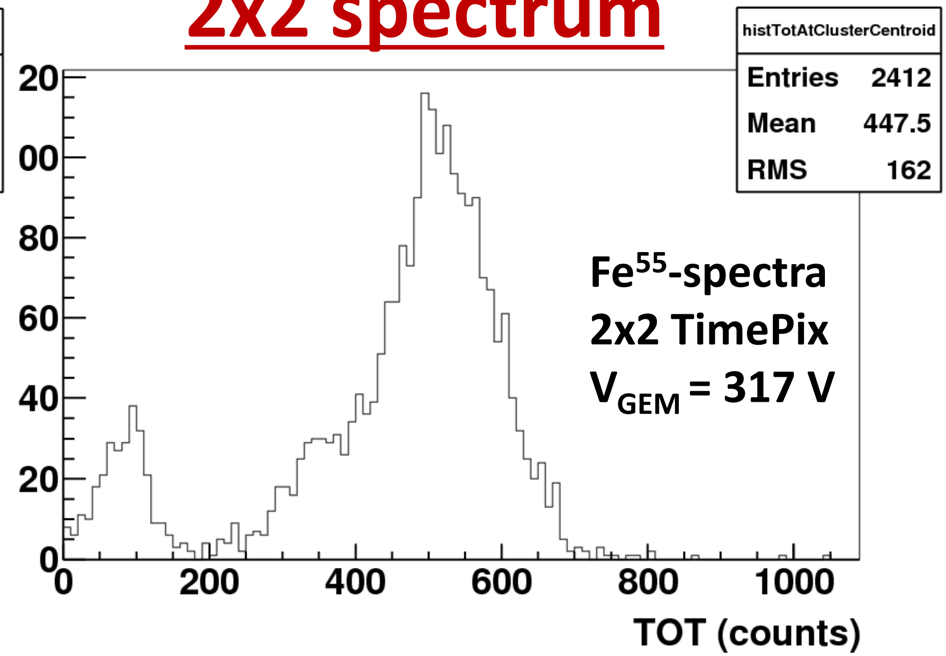
passivated pixels

TOT at Cluster Centroid-Spectra

1x1 spectrum



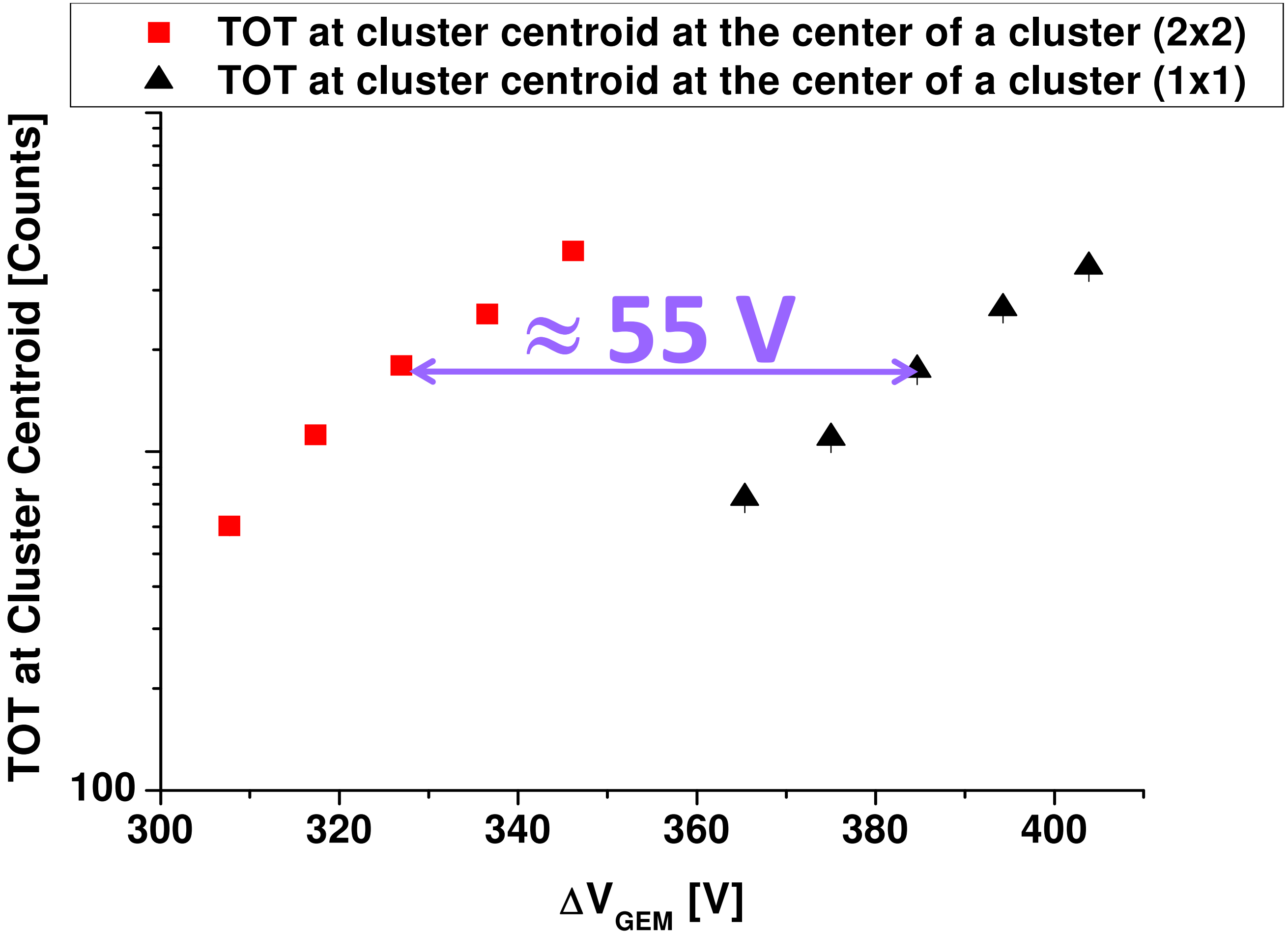
2x2 spectrum



- To compare 1x1 and 2x2: Determine peak position for different GEM voltages.
- Look for same TOT value of 1x1 and 2x2 and estimate difference in ΔV_{GEM}.
- Problem:
  - » Different thresholds for 1x1 and 2x2 TimePix
  - » Different readout interfaces $\Rightarrow$ different clocks must be corrected
  - » Other systematic uncertainties are investigated

18

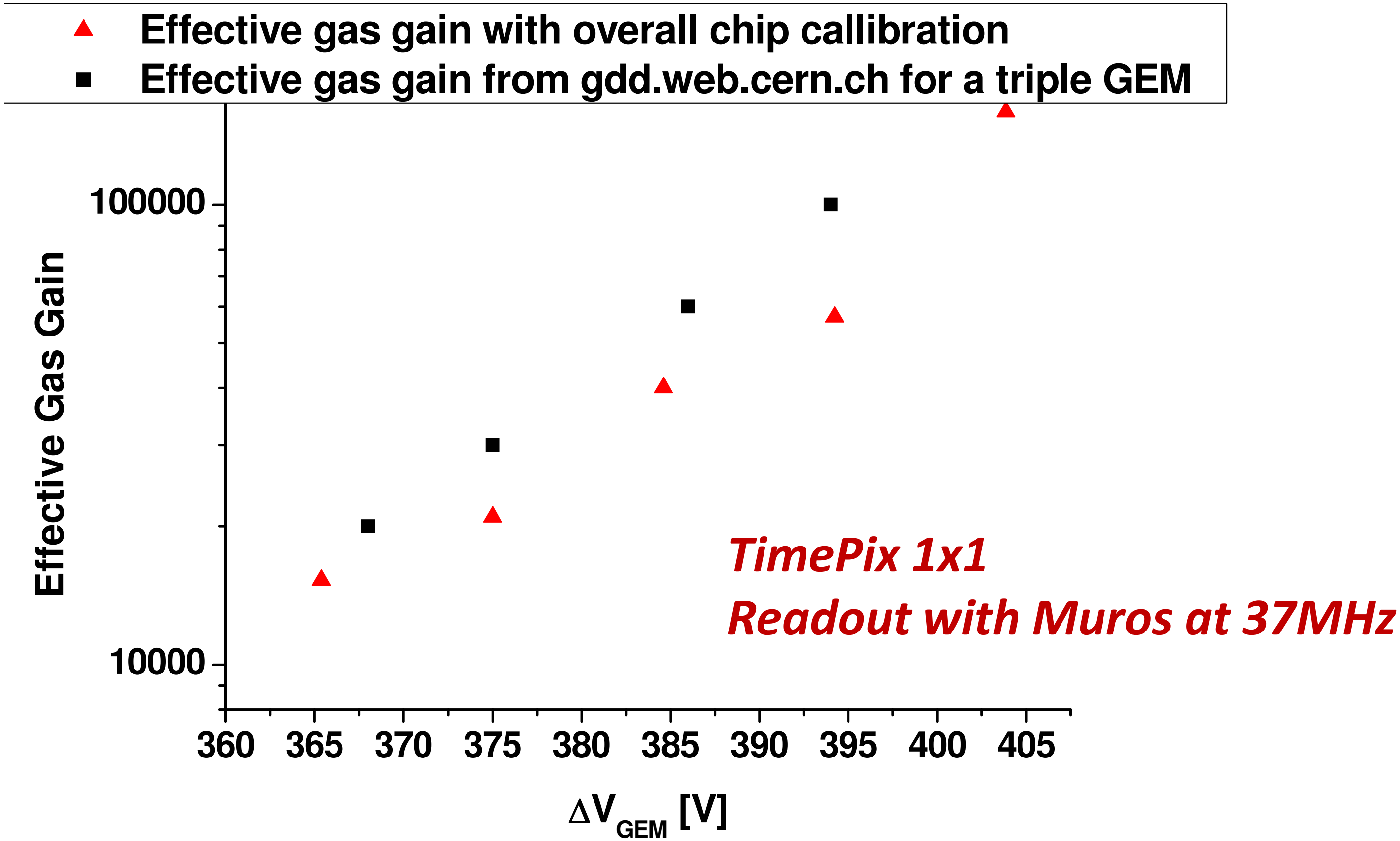
TOT Counts at Cluster Centroid vs. ΔV_{GEM}



- To account for different clocks 1x1 results are corrected with factor 80/37.
- For about same TOT value ≈55V smaller ΔV_{GEM}
- Lower effective threshold ⇒ Less backflow of positive ions into drift volume.

Gain Estimation

- "Recipe" to calibrate TOT with test pulses:
  - » Charge of injected test pulses (TimePix-Manual): Q = 50[e^-/V] x TestPulse[V]
  - » Conversion factor from TOT count to charge ("chipwise").
- Estimate Charge deposition from TOT volume of a cluster.



Full post-processing of a TimePix

· Timepix chip + SiProt + Ingrid:

Timepix chip:

•256x256 pixels

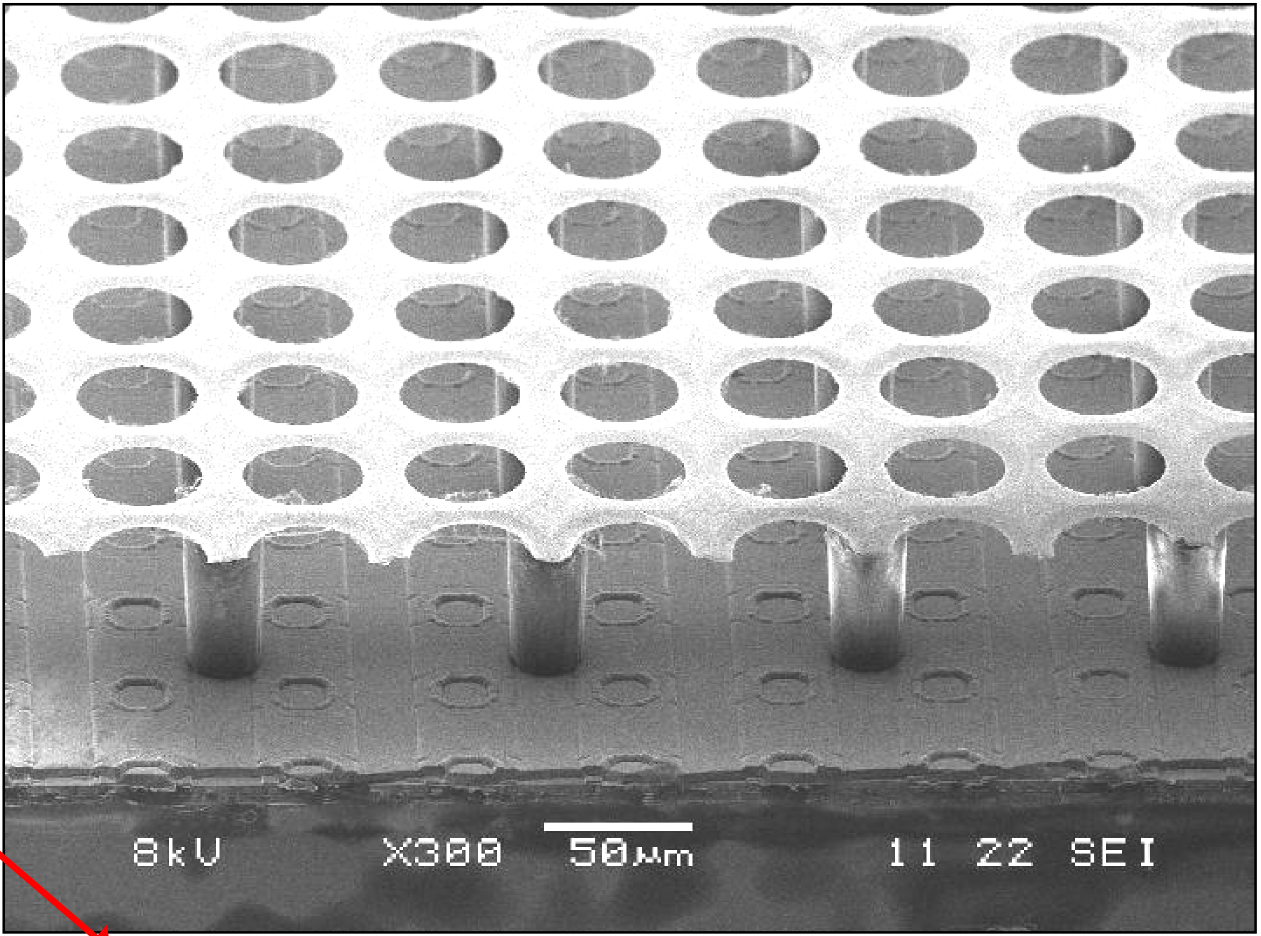
•pixel: 55x55 μm^2

•active surface: 14x14 mm^2

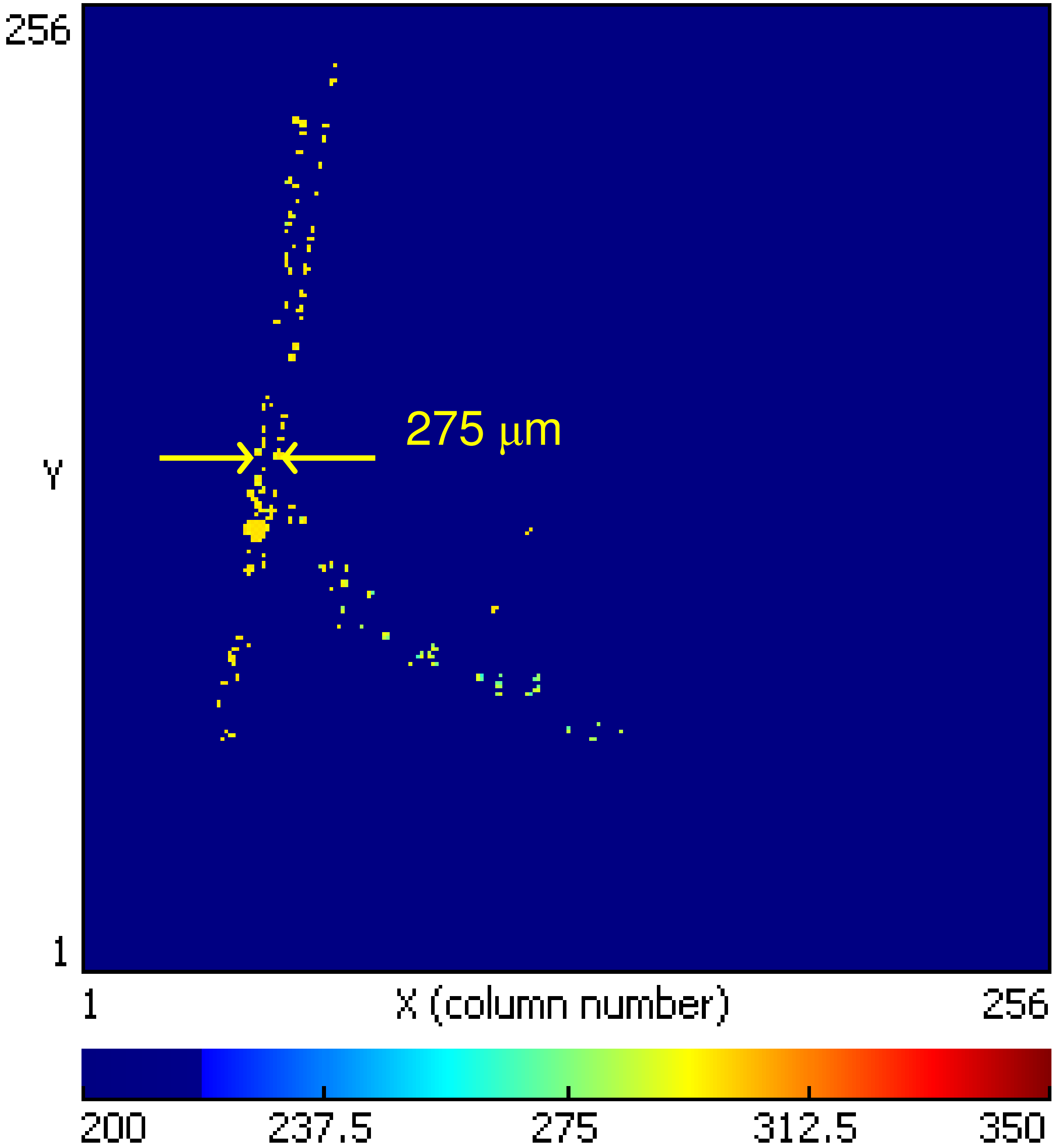
MESA+: Ingrid

IMT Neuchatel:

15 or 20 µm highly resistive aSi:H protection layer



Now also Si_3N_4 protection layers (7 µm)



Two-track separation:

•Will be diffusion limited

•In this example:

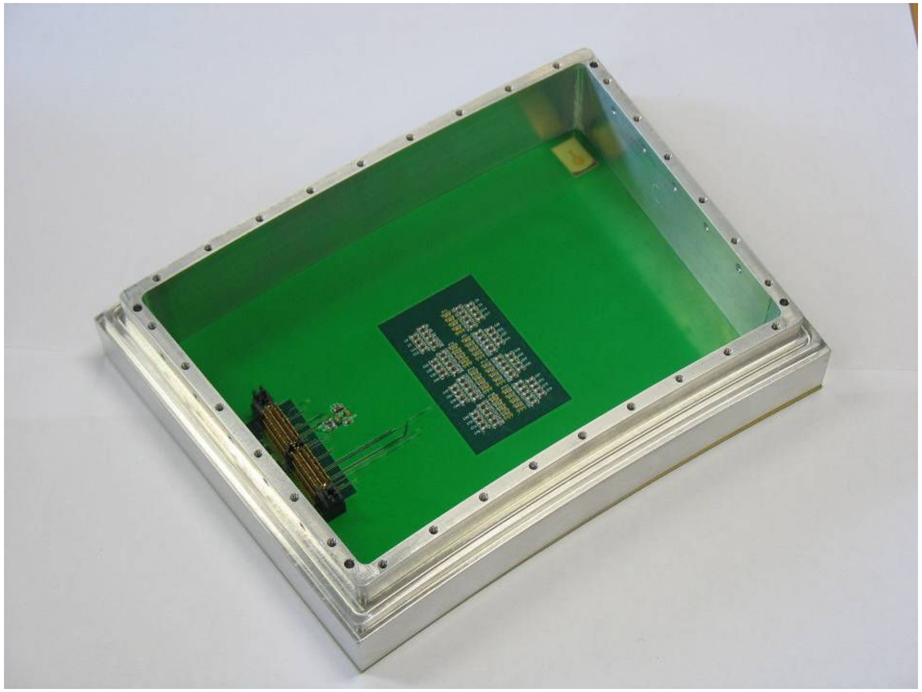
5 pixels = 275 μm

Diffusion at 4T in

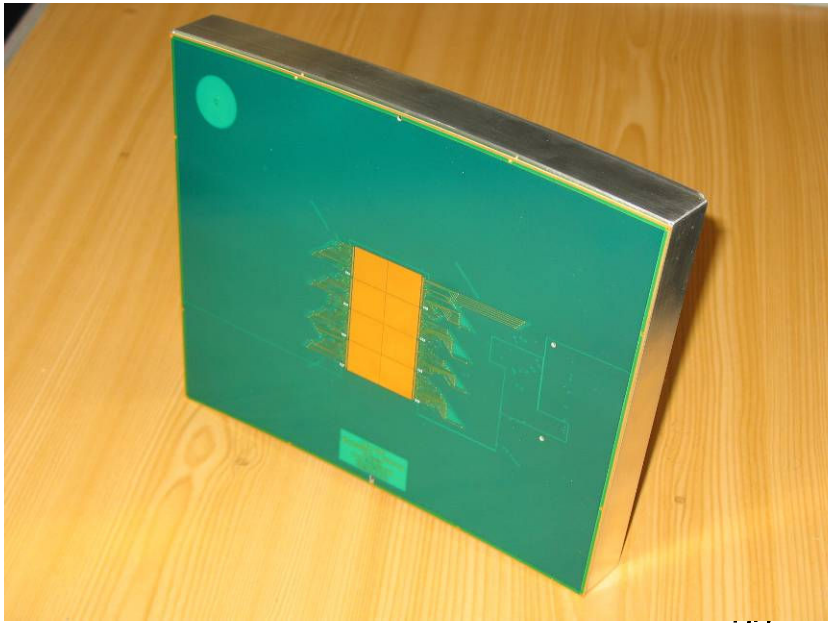
$Ar/CF4/iC_4H_{10}$ is

~ $20\sqrt{200}$ = 300 μm

Saclay

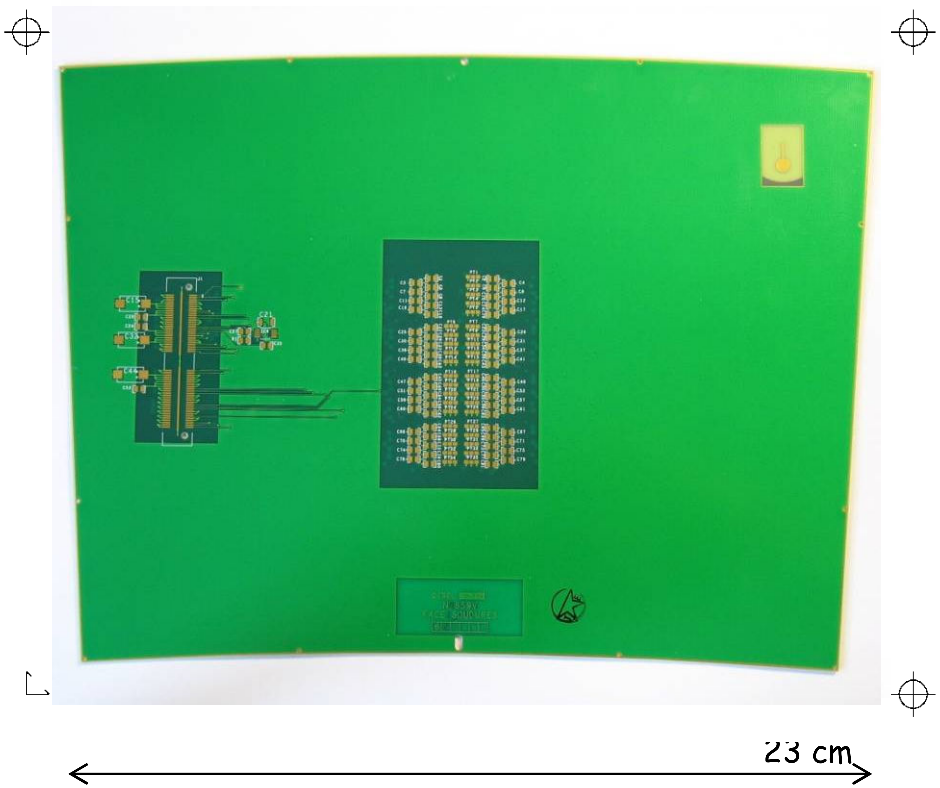


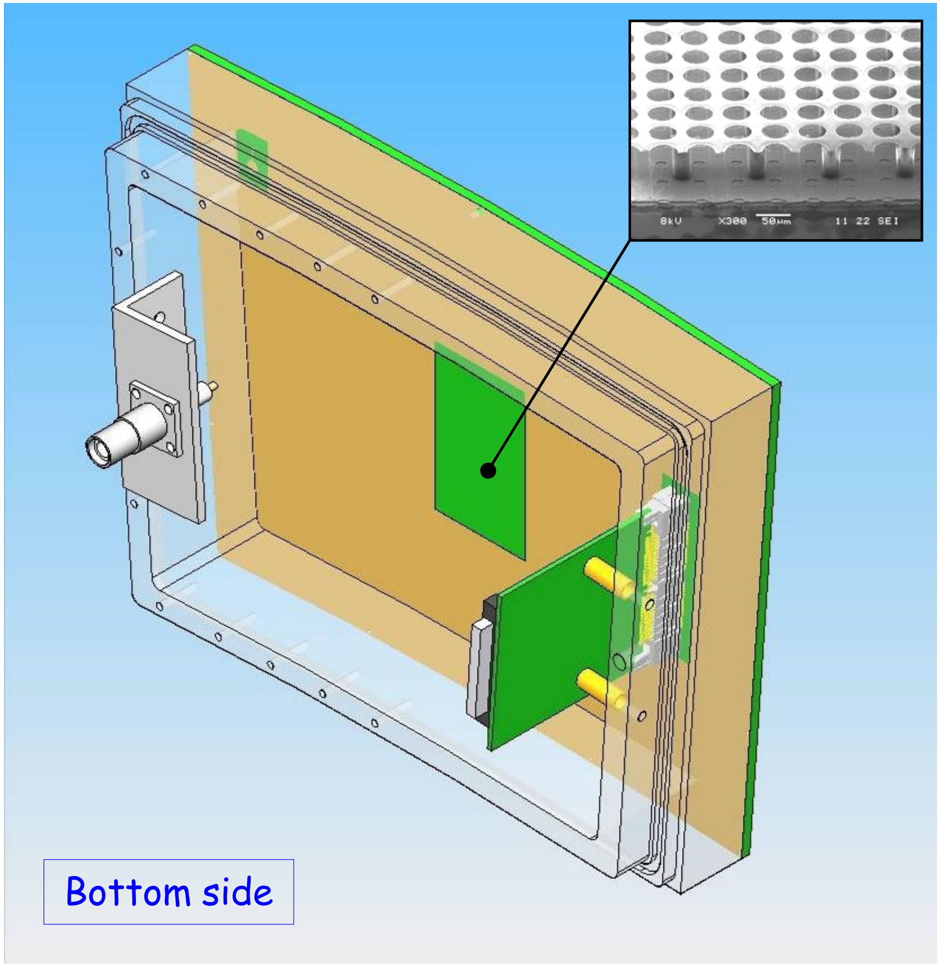
- bug in Pixelman software fixed
- Now Ingrids available from Nikhef/Twente
- Expect module for test early 2010
- 8 Timepix chips



TimePix/Ingrid Panel

- TimePix panel with a 2x4 matrix of TimePix chips + InGrids for the TPC Large Prototype
- 6-layers PCB
- Transfert card for VHDCI cable





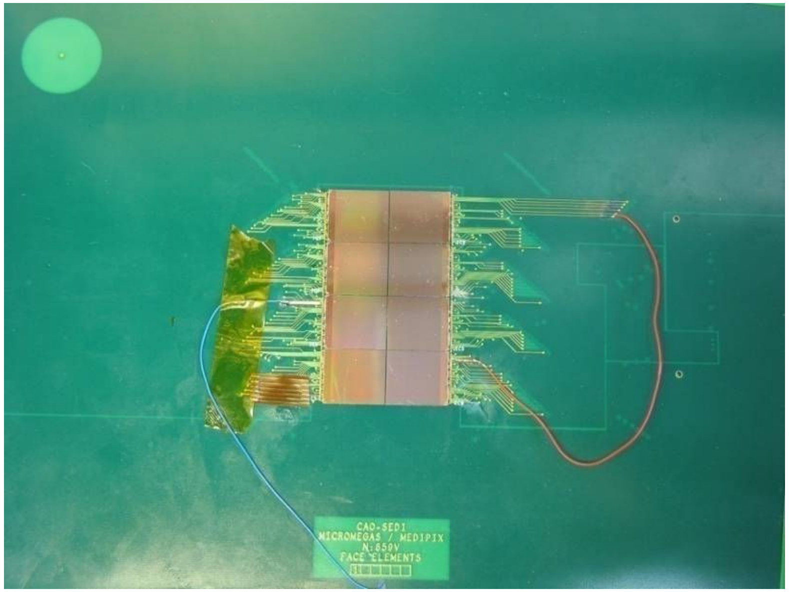
First tests

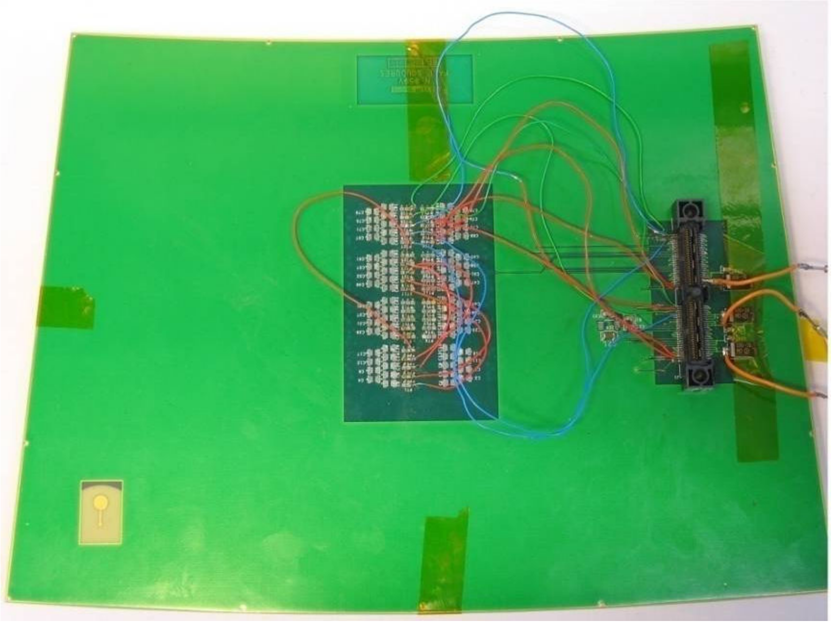
- 8 TimePix chips have been connected on the PCB
  - issues for the wire bonding

  → two chips were broken by the bonding factory

- Electrical test
  - an error of routing was found and corrected using external wires
  - power supply by MUROS only was insufficient (0.2 A per puce)

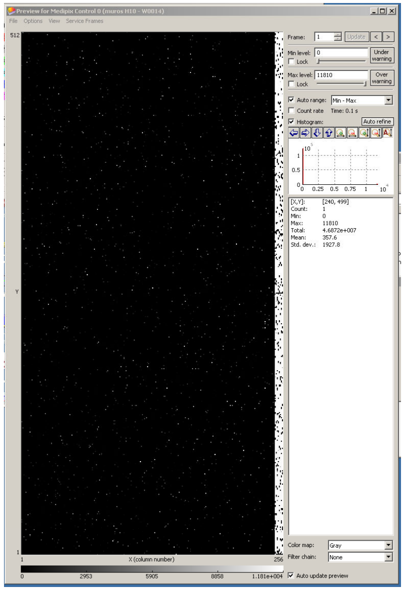
  → 3 voltage to stabalize (LV) to 2.2V

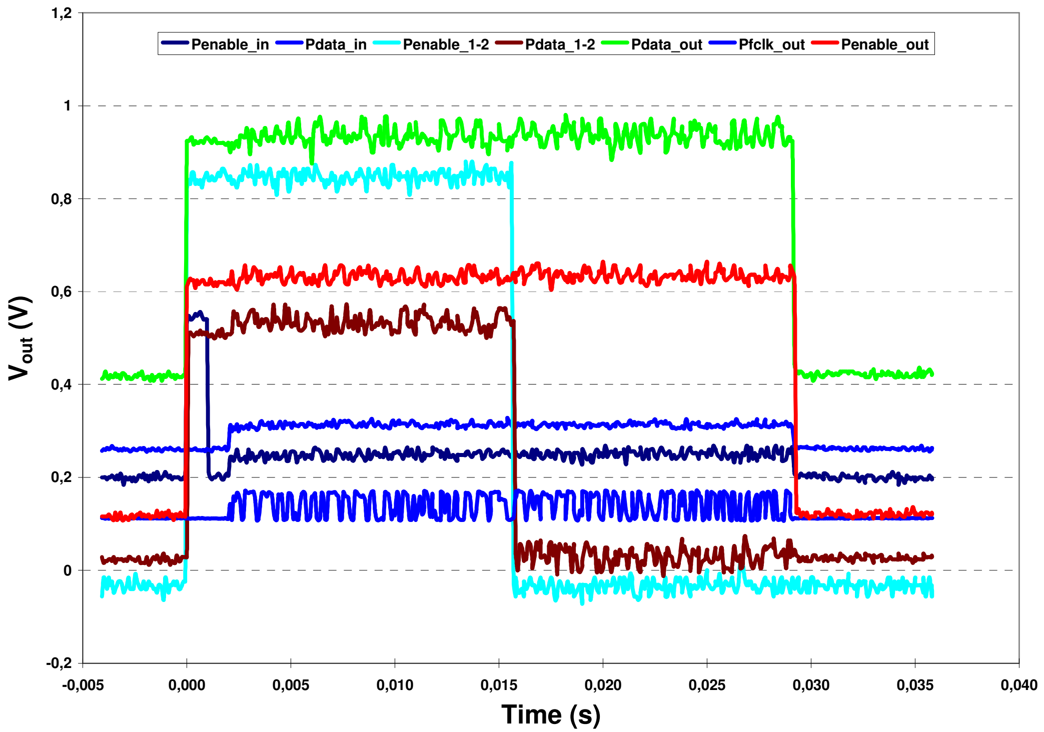


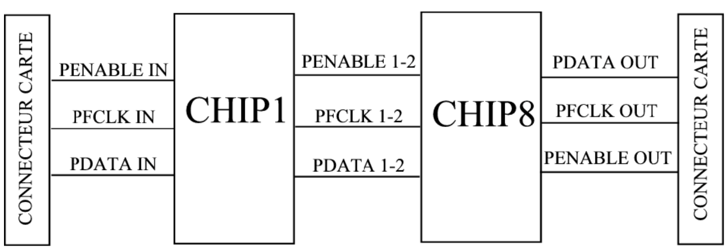


Test with 2 chips

- The 8 chips were removed and replaced by only two
- New test at CERN (January 20th, 2009)
  - the hardware was validated
  - but, correction needed in the official software Pixelman







New card in progress

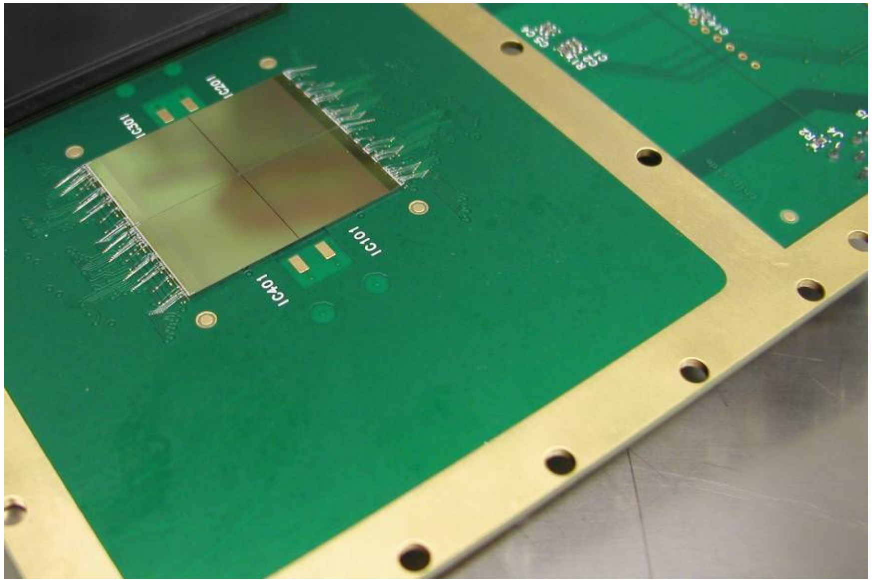
- A new card was designed taking into account what we learn with the previous
- New design :

  - the 2x4 matrix is place on top a mezzanine to make easier the wire bonding

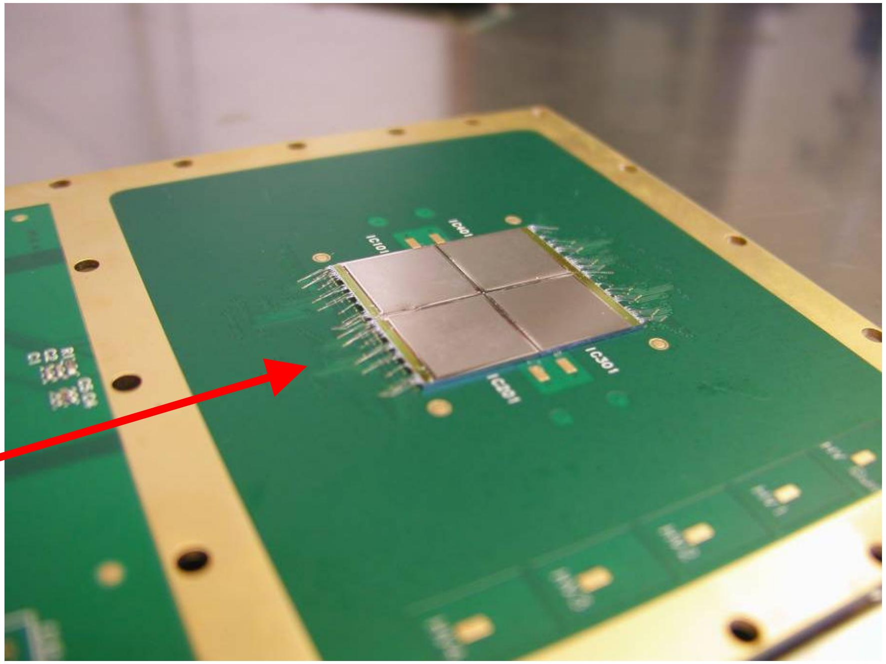
  - power regulators was implemented

- Ingrids → a batch of 8 (+3 spare) Ingrids are now at Saclay
- Should be tested on the Large Prototype TPC early next year

NIKHEF: emphasis on Ingrids

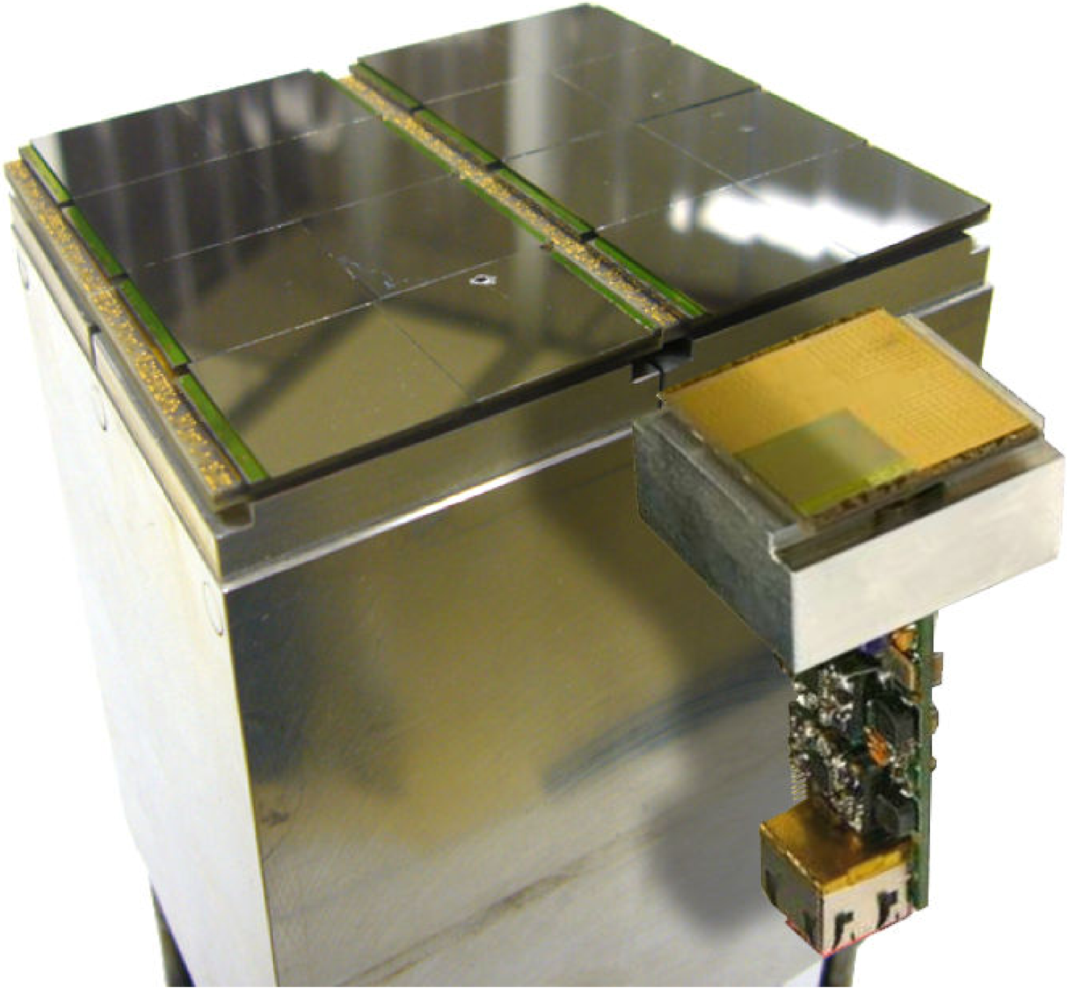


- within Relaxed project: 4x4 Medipix chips in compact mounting
- Will evolve in 8x8 Timepix chips for EUDET



- QUAD chips board tested OK in 2008
- Equiped with Ingrids in June ‘09
- Could become standalone “traveling” TA infrastructure

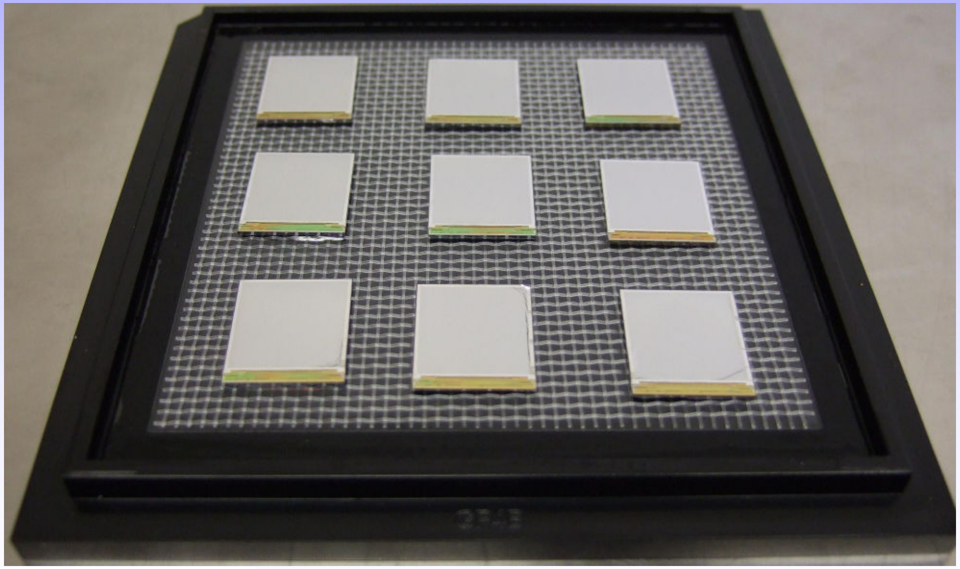
NIKHEF

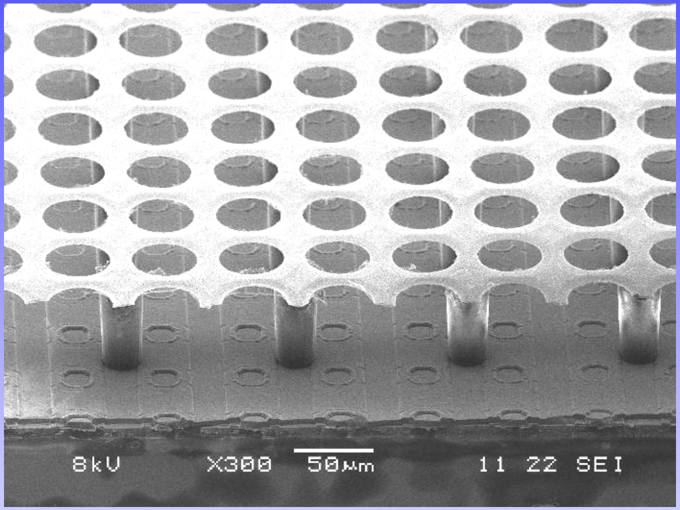


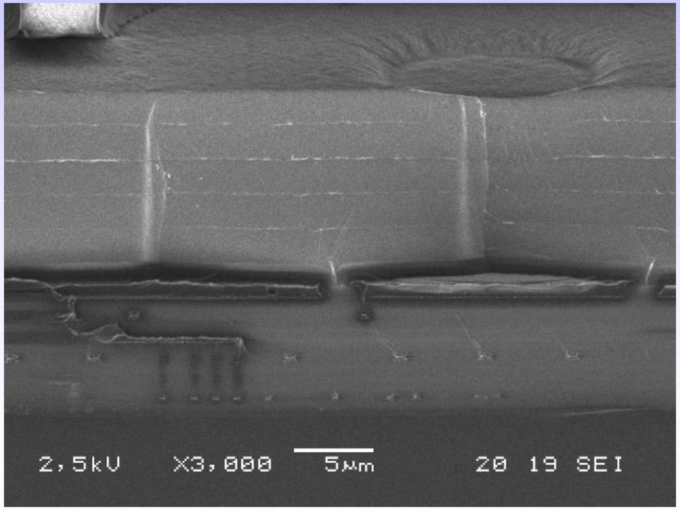
- within Relaxed project: 4x4 Medipix chips in compact mounting
- Will evolve in 8x8 Timepix chips for EUDET

Chip post processing

- Since October 2009 acceptable yield from parallel processed TimePix chips
- First batch of those to Saclay (finally!) for end modules







NIKHEF

Beamtests at DESY

- Characterize Gridpix detectors:
- TimePix chips with 2,4,6,and 8 um silicon nitride
- 11.5 mm drift gaps
- Used gases:
  - Ar/ISO 80:20
  - He/ISO 80:20
  - T2K, Ar/CF4/ISO 95:3:2
  - Ar/CO2 70:30
  - He/CO2 70:30

- 4um silicon nitride appears to be sufficient
- Still those sudden "soft deaths" to solve
- All detectors work fine in He/Iso mixture
- 1 good detector works fine in Ar/iso mixture
- No plateau reached in other gasses

Several single chip systems produced for:

- Test detector performance with different thickness of Si_3N_4 protection layers (in DESY T22 beam)
- Test efficiency and resolution in Gossip-like geometry (only 1.5 mm gas layers) in CERN testbeam

- Data analysis in progress
- Sometimes still discharges that kill Timepix chips; some indication it is on the 'outside' edges of Ingrid/Timepix

- R&D on fast optical data connection based on interferometer and ideas about optical power connections being worked on (→ slides Martin Fransen)

Results single point resolution
(from 2008 CERN PS testbeam)

gas	E_{drift} (V/cm)	D_t exp ($\mu m/\sqrt{cm}$)	$\sigma_{xy,0}$ (μm)
Ar 3% CF_4 2% IsoBut	200	290	35±11
Ar 30% CO_2	470	148	24±7
Xe 30% CO_2	1000	185	30±15
Xe 30% CO_2	1400	103	23±11
Xe 30% CO_2	1900	110	17±14
He 20% IsoBut	560	175	27±14

Master thesis Lucie de Nooij (NIKHEF)

Error includes (syst.) error due to T-zero (extrapolation to z=0)

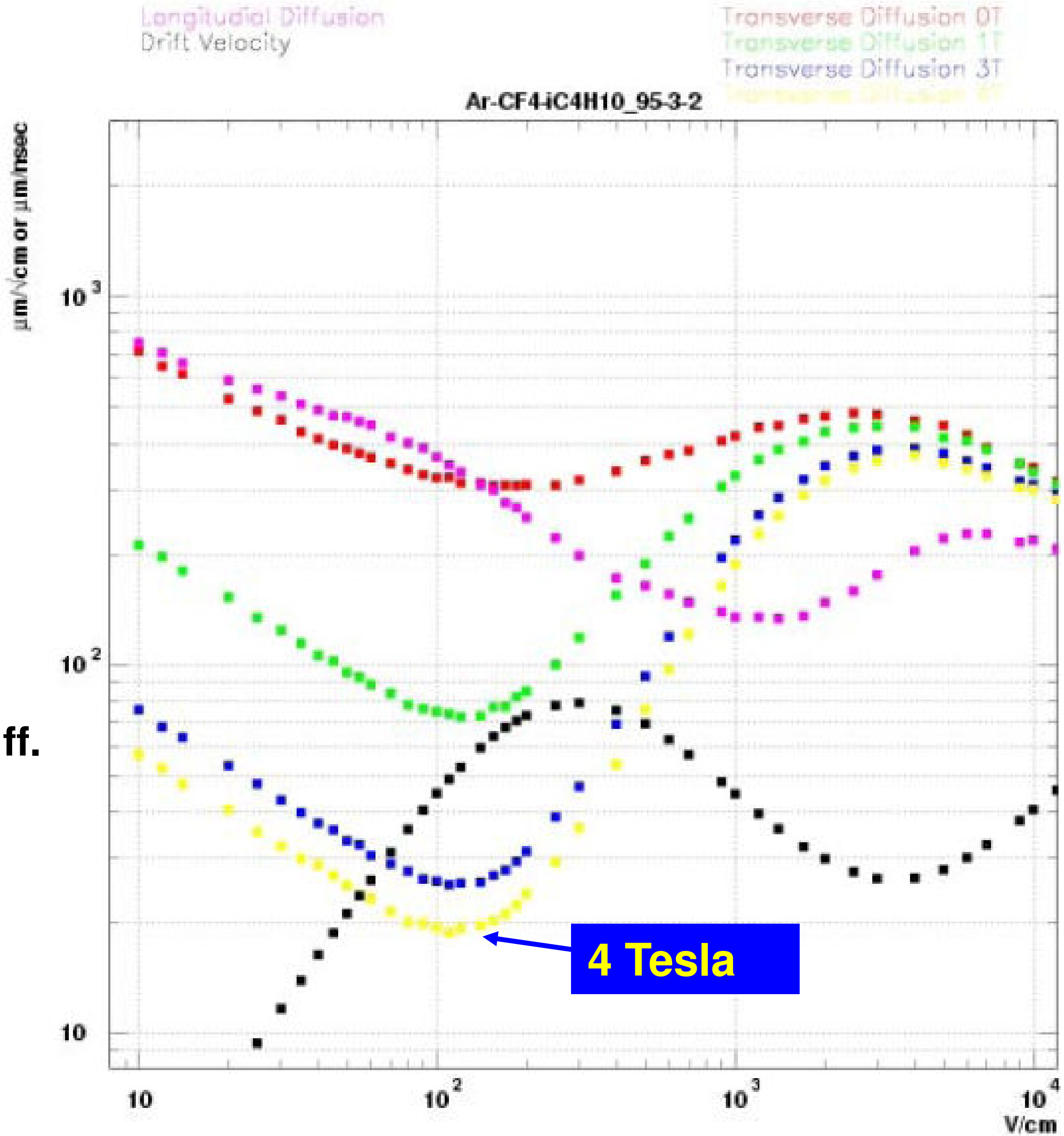
All groups have established contacts with outside institutions for 8” wafer scale post-processing:

- Freiburg Metallforschungszentrum (pixel enlargement)
- IZM Berlin: Ingrid technology
- SMC (Scottish Microelectronics Centre) Edinburgh: Ingrid technology
- LAAS (CNRS) Toulouse (max. 6” wafers)

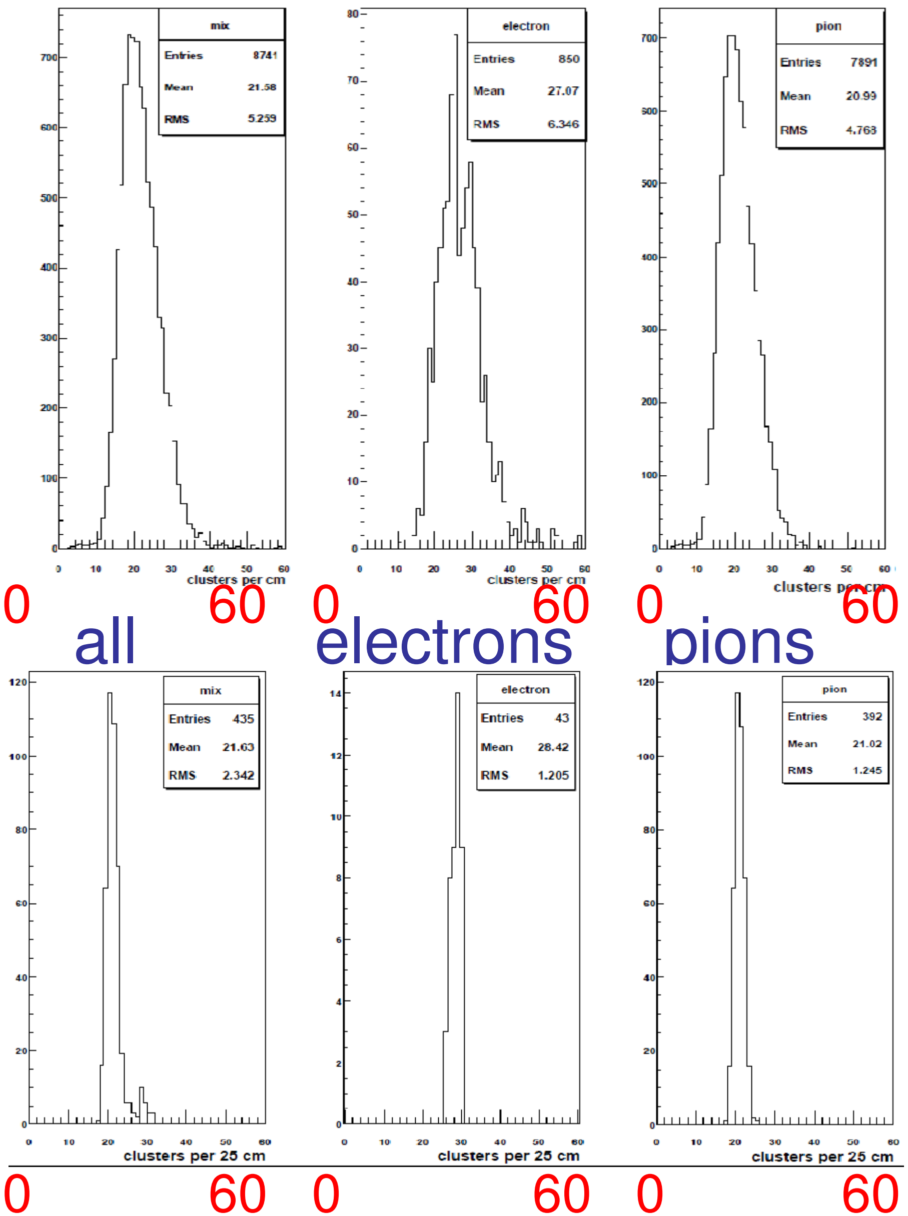
Summary

- SITPC final infrastructure deliverable available (1st "leg"); testbeam data analysis ongoing
- Now sufficient number of Ingrids to equip 2nd "leg"; 8 (+3 spare) Ingrids available now
- Test of 2nd "leg" at LP before early 2010
- 3rd "leg" with Quad-Ingrid detector(s) ready for tests.

Backup slides


Longitudial Diffusion
Drift Velocity
Transverse Diffusion 0T
Transverse Diffusion 1T
Transverse Diffusion 3T
Ar-CF4-iC4H10_95-3-2
μm/√cm or μm/nsec
V/cm
4 Tesla
Transv. Diff.
Long. Diff.
Drift vel.

Cluster counting distribution in He/iC4H10



- Using 1 cm tracklength

Electrons:

Avg=27.1/cm rms=6.3

Pions: 21.0/cm 4.8

- Using 25 cm tracklength

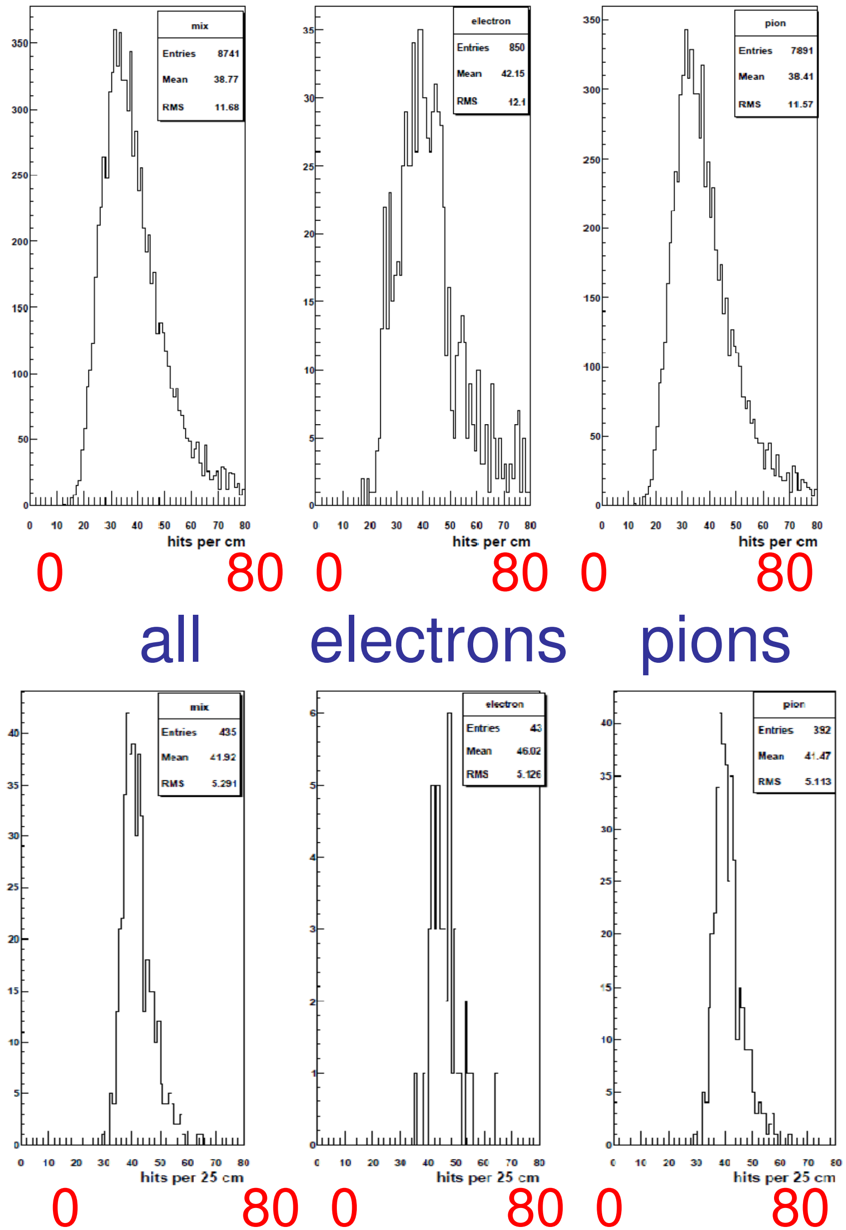
Electrons:

Avg=28.4/cm rms=1.2

Pions: 21.0/cm 1.2

4.4 σ difference

Single hits counting distribution in He/iC4H10



- Using 1 cm tracklength

Electrons:

Avg=42.2/cm rms=12.1

Pions: 38.4/cm 11.6

- Using 25 cm tracklength

Electrons:

Avg=46.0/cm rms=5.1

Pions: 41.5/cm 5.1

0.6 σ difference